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Original Article

Digit Ratio (2D:4D) and Gender Inequalities Across Nations

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Abstract: Gender inequality varies across nations, where such inequality is defined as the disproportionate representation of one sex over the other in desirable social, economic, and biological roles (typically male over female). Thus in Norway, 40% of parliamentarians are women, in the USA 17%, and in Saudi Arabia 0%. Some of this variation is associated with economic prosperity but there is evidence that this cause and effect can go in either direction. Here we show that within a population the average ratio of index (2D) to ring (4D) finger lengths (2D:4D)—a proxy measure of the relative degree to which offspring is exposed in utero to testosterone versus estrogen—is correlated with measures of gender inequality between nations. We compared male and female 2D:4D ratios to female parliamentary representation, labor force participation, female education level, maternal mortality rates, and juvenile pregnancy rates per nation in a sample of 29 countries. We found those nations who showed higher than expected female fetal exposure to testosterone (low 2D:4D) and lower than expected male exposure to fetal testosterone (high 2D:4D) had higher rates of female parliamentary representation, and higher female labor force participation. In short, the more similar the two sexes were in 2D:4D, the more equal were the two sexes in parliamentary and labor force participation. The other variables were not as strongly correlated. We suggest that higher than expected fetal testosterone in females and lower fetal testosterone in males may lead to high female representation in the national labor force and in parliament.

Keywords: gender inequality, digit ratio, 2D:4D, prenatal hormones, parliamentary representation, labor force

Introduction

Women's political empowerment often appears severely impaired. Women commonly experience low rates of parliamentary representation, unequal labor force participation, low educational attainment, high rates of maternal mortality, and adolescent fertility (United Nations, 2014; United Nations Development Programme [UNDP], 2011). Within the overall pattern of gender inequality (GI), there are variations in women's empowerment across regions and nations. With regard to regional variation, in South Asia there are marked gender disparities in parliamentary representation, labor force participation, and education. In Arab states, women's labor force participation is about half the global average and educational levels are low. Sub-Saharan Africa also has low educational attainment among women, in addition to high rates of maternal mortality and teenage fertility (UNDP, 2011). With regard to national variation, a ranking of countries based on a composite measure of GI (the Gender Inequality Index; GII) showed a tendency to rank Northern European countries highly for gender equality (e.g., Sweden: rank 1; Netherlands: 2; Denmark: 3; Switzerland: 4; Finland: 5), whereas other developed nations ranked lower (e.g., UK rank: 34; USA: 47) (see UNDP, 2011). The factors influencing the variance in GI across similar nations are unclear. For example, economic growth across nations is negatively related to GI, and reductions in GI—particularly in female labor force participation—are related to increases in economic growth (Kabeer and Natali, 2013). However, it is easy to imagine causality working in the opposite direction, with working women having experienced a more testosterone-rich prenatal environment. Here we show that digit ratio (2D:4D), a proxy for prenatal testosterone and prenatal estrogen, is correlated with aspects of GI.

Digit ratio—the relative length of index (2D) to ring (4D) finger—is a sexually dimorphic trait, with males typically having lower values of 2D:4D than females. The sex difference in 2D:4D is determined early in ontogeny, presumably by the end of the first trimester (Galis, Ten Broek, Van Dongen, and Wijnaendts, 2010; Malas, Dogan, Evcil, and Desdicioglu, 2006), and remains virtually unchanged through childhood and puberty (Manning, Scutt, Wilson, and Lewis-Jones, 1998; McIntyre, Ellison, Lieberman, Demerath, and Towne, 2005; Trivers, Manning, and Jacobson, 2006). Although the sex difference is small, there is substantial variation in 2D:4D within each sex; this variation is associated with variations in fetal exposure to testosterone and estrogen, with testosterone increasing the relative size of the fourth digit and estrogen shortening it (Manning, 2002, 2008). Subsequent experimental studies of mice (Zheng and Cohn, 2011) and rats (Auger et al., 2013) have supported this model. Likewise, 2D:4D has been shown to deviate from human norms in the expected directions in such conditions as elevated testosterone (congenital adrenal hyperplasia; see Hönekopp and Watson, 2010 for meta-analysis), androgen insensitivity (Berenbaum, Bryk, Nowak, Quigley, and Moffat, 2009), and low prenatal testosterone (Klinefelter's syndrome; Manning, Kilduff, and Trivers, 2013).

The following work suggests that this variable may be related to such society-wide phenomena as relative labor participation by the two sexes. Manning, Reimers, Baron-Cohen, Wheelwright, and Fink (2010) reported that 2D:4D is associated with occupational gender segregation. Women with low 2D:4D are overrepresented in occupations with a high percentage of men (e.g., engineering, IT, and manufacturing), leading to the conclusion that high prenatal testosterone may have an organizational effect on female abilities in, and preferences for, male-typical occupations. Manning and Fink (2008) also reported a relationship between 2D:4D and dominance. Individuals with low 2D:4D scored higher on a composite measure of dominance behaviors, such as the imposition of one's will upon others, demanding explanations from others, or challenging other's points of view. Finally, Manning and Fink (2011) found that mean 2D:4D per nation was negatively related to aggregated national personality scores of uncertainty avoidance, and GDP was linked to low 2D:4D in women.

These findings led us to predict that nations with small sex differences in mean 2D:4D would show low GI. Therefore, the present study considered mean national male and female 2D:4D and their relationships with national GII scores. We predicted a positive relationship between GII scores and the magnitude of sex differences in mean 2D:4D.

Materials and Methods

Participants

Participants were recruited from an internet study—hosted by the BBC Science and Nature websites—that included questions about demographics, personality, social attitudes, and behavior, along with cognitive tests and self-measurement of physical characteristics such as 2D and 4D length (see Reimers, 2007 for details). The total sample size in this study was 158,753 participants (71,186 women). The nations with the smallest sample sizes included Iceland (161), Argentina (171), Hungary (191), Croatia (193), and the Czech Republic (225). Those with the largest sample sizes were the Republic of Ireland (4,421), Australia (6,672), Canada (9,077), USA (37,988), and the UK (84,236). The mean sample size per nation was 5,473.93 (SD = 16,725). The mean age per nation ranged from 24.9 years to 34.97 years, with a mean of 30.24 (SD = 2.80) years. White participants made up the most abundant ethnicity. As 2D:4D is substantially influenced by ethnicity, we only considered nations that were predominantly White and removed non-Whites from the sample. The minimum number of respondents per nation was 150. A total of 29 nations were included in the statistical analysis.

Measures and procedure

All participants were requested to provide self-measured finger lengths following the methodology reported by Manning et al. (1998). After viewing a diagram of the hand, they were given instructions as to how to measure their index finger and ring finger on the palm-side of their right and left hands. The participants were asked to measure finger lengths with a ruler and report lengths to the nearest millimeter using dropdown menus, with values between 10 and 100 mm in 1 mm increments. The analysis was restricted to a 2D:4D range of 0.80 to 1.20, with more extreme values excluded. National averages for GI and Gross National Income (GNI) per capita were obtained from the UNDP (2011). Gender inequality measures included: the percentage of parliamentary seats held by women (parliamentary representation), the percentage of working age women employed in the labor force (labor force participation), the percentage of women 25 and older who have reached secondary education, the ratio of maternal deaths to live births (maternal mortality ratio), the number of births per 1,000 women aged 15-19 (adolescent fertility rate), and the overall measure of GII composed of health, empowerment, and labor market dimensions.

Results

Mean (± *SD*) 2D:4D per nation showed significant sex differences for both right 2D:4D (men: .984 ± .003; women: .994 ± .004; paired $t = 13.41$, $p < .0001$) and left 2D:4D (men: .985 ± .002; women: .993 ± .004; paired $t = 9.61$, $p < .0001$) (see Table 1).

Table 1. Digit ratios (2D:4D) by sex and hand in 29 nations

	Mean (*SD*)				Residuals	
Nation	R2D:4D Male	L2D:4D Male	R2D:4D Female	L2D:4D Female	R2D:4D	L2D:4D
Argentina	.989 (.047)	.986 (.038)	.992 (.057)	.992 (.058)	-.006	-.001
Australia	.982 (.046)	.983 (.045)	.99 (.046)	.989 (.044)	-.002	-.002
Austria	.98 (.04)	.987 (.042)	.989 (.043)	.992 (.038)	-.002	-.002
Belgium	.981 (.044)	.984 (.043)	.99 (.047)	.99 (.044)	-.001	-.002
Bulgaria	.99 (.048)	.989 (.047)	.997 (.049)	.998 (.048)	-.001	.003
Canada	.982 (.048)	.982 (.047)	.995 (.05)	.993 (.049)	.003	.002
Croatia	.980 (.039)	.984 (.038)	.998 (.038)	.997 (.037)	.007	.005
Czech Republic	.984 (.04)	.986 (.042)	1.00 (.048)	.999 (.044)	.006	.006
Denmark	.982 (.04)	.988 (.045)	.986 (.045)	.99 (.048)	-.006	-.004
Finland	.983 (.046)	.985 (.044)	.991 (.044)	.991 (.042)	-.002	-.001
France	.984 (.044)	.988 (.043)	.990 (.046)	.987 (.044)	-.004	-.007
Germany	.983 (.043)	.986 (.041)	.994 (.046)	.992 (.043)	.001	-.001
Greece	.987 (.049)	.987 (.045)	.997 (.054)	.999 (.05)	.001	.005

Nation	Mean (*SD*) R2D:4D Male	Mean (*SD*) L2D:4D Male	Mean (*SD*) R2D:4D Female	Mean (*SD*) L2D:4D Female	Residuals R2D:4D	Residuals L2D:4D
Greece	.987 (.049)	.987 (.045)	.997 (.054)	.999 (.05)	.001	.005
Hungary	.986 (.041)	.989 (.039)	1.00 (.051)	.996 (.048)	.005	.001
Iceland	.982 (.052)	.986 (.047)	.986 (.051)	.988 (.049)	-.006	-.005
Rep. Ireland	.982 (.048)	.983 (.047)	.991 (.05)	.991 (.049)	-.001	-3.369e-4
Italy	.985 (.041)	.987 (.044)	.996 (.048)	.991 (.047)	.001	-.003
Netherlands	.981 (.047)	.985 (.045)	.990 (.048)	.992 (.047)	-.001	-4.544e-4
New Zealand	.981 (.046)	.983 (.045)	.989 (.047)	.988 (.043)	-.002	-.003
Norway	.981 (.043)	.984 (.042)	.991 (.049)	.99 (.049)	-5.000e-4	-.002
Poland	.984 (.05)	.989 (.045)	1.00 (.046)	.997 (.043)	.006	.002
Portugal	.984 (.051)	.984 (.049)	.989 (.049)	.987 (.038)	-.005	-.005
Romania	.986 (.05)	.985 (.047)	.997 (.048)	1 (.048)	.002	.008
Spain	.987 (.053)	.988 (.045)	.995 (.044)	.992 (.048)	-.001	-.002
Sweden	.982 (.049)	.982 (.046)	.994 (.05)	.992 (.048)	.002	.001
Switzerland	.984 (.041)	.983 (.041)	.992 (.046)	.988 (.039)	-.002	-.003
Turkey	.984 (.041)	.985 (.049)	1.002 (.049)	1.002 (.049)	.008	.01
United Kingdom	.985 (.048)	.986 (.046)	.993 (.05)	.992 (.047)	-.002	-.001
United States	.985 (.055)	.985 (.051)	.998 (.055)	.994 (.053)	.003	.002

Note. R2D:4D = right hand digit ratio; L2D4D = left hand digit ratio

There was a significant positive correlation between mean national 2D:4D for men and women for right 2D:4D ($r = 0.44$, $p < 0.05$), but not for left 2D:4D ($r = 0.28$, $p = 0.14$). In order to focus on disparities between male and female mean 2D:4D, we regressed female 2D:4D on male 2D:4D and considered the residuals (*res2D:4D*) as a measure of sex difference per nation (see Table 1). Negative residuals indicate women have lower 2D:4D (more prenatal testosterone and less prenatal estrogen) than expected in comparison to male 2D:4D and positive values indicate women have higher 2D:4D (less prenatal testosterone and more prenatal estrogen) than expected in comparison to men. The correlation between right *res2D:4D* and left *res2D:4D* was high ($r = 0.79$, $p < 0.0001$).

Table 2 reports measures of gender inequality (% female parliamentary seats, % female labor force participation, female secondary education, maternal mortality ratio, adolescent fertility rate, and an overall measure of inequality, the GII) in 29 nations. The descriptive statistics (mean ± *SD*) were as follows: female parliamentary seats: 27.79% ± 9.78%; female labor force participation: 52.8% ± 8.43%; female secondary education: 81.40% ± 19.18%; maternal mortality ratio: 12.10 ± 13.92; adolescent fertility rate: 14.63 ± 11.62; GII: .15 ± .09.

Table 2. Six measures of gender inequality in 29 nations

Nation	Parl. Seats Female	Lab. Force Female	Educ. Att. Female	Maternal Mortality	Adolescent Fertility	GII	GNI per Capita
Argentina	37.7	47.3	57	77	54.2	.38	14527
Australia	29.2	58.8	92.2	7	12.5	.115	34431
Austria	28.7	53.9	100	4	9.7	.102	35719
Belgium	38.9	47.7	76.4	8	11.2	.098	33357
Bulgaria	20.8	48.6	90.9	11	36.2	.219	11412
Canada	28	61.9	100	12	11.3	.119	35166
Croatia	23.8	46	57.4	17	12.8	.179	15729
Czech Republic	21	49.6	99.8	5	9.2	.122	21405
Denmark	39.1	59.8	99.3	12	5.1	.057	34347
Finland	42.5	55.9	100	5	9.3	.075	32438
France	25.1	51.1	75.9	8	6	.083	30462
Germany	32.4	53	96.2	7	6.8	.075	34854
Greece	21	44.8	57.7	3	9.6	.136	23747
Hungary	8.8	43.8	93.2	21	13.6	.256	16581
Iceland	39.7	70.8	91	5	11.6	.089	29354
Ireland	19	52.6	74.8	6	8.8	.121	29322
Italy	20.7	37.9	68	4	4	.094	26484
Netherlands	37.8	58.3	87.5	6	4.3	.045	36402
New Zealand	32.2	61.6	82.8	15	18.6	.164	23737
Norway	39.6	61.7	95.6	7	7.4	.065	47557
Poland	21.8	48.2	76.9	5	12.2	.14	17451
Portugal	28.7	56.5	40.9	8	12.5	.114	20573
Romania	9.7	48.6	83.4	27	28.8	.327	11046
Spain	34.9	51.6	63.3	6	10.7	.103	26508
Sweden	44.7	59.4	84.4	4	6.5	.055	35837
Switzerland	26.8	60.6	95.1	8	3.9	.057	39924
Turkey	14.2	28.1	26.7	20	30.5	.366	12246
United Kingdom	22.1	55.6	99.6	12	29.7	.205	33296
United States	17	57.5	94.7	21	27.4	.256	43017

Table 3 reports relationships by sex and by hand for mean 2D:4D and our six measures of gender inequality. In general, there were stronger associations for the right hand compared to the left. It was noteworthy that the direction of the associations were the same in both sexes with (i) significant male and female negative correlations between right and left 2D:4D and female parliamentary seats and female labor force participation, (ii) a significant male and non-significant female positive correlation between right 2D:4D and maternal mortality and adolescent fertility rate, and (iii) significant positive correlations between 2D:4D and GII for men (right hand only) and women (right and left hands).

Considering GNI, the mean per capita was \$27,825.14 ± 9875.90. There was a significant negative relationship between GNI and left *res2D:4D* ($r = -.52$, $p < .01$), but not right *res2D:4D* ($r = -.31$, $p = .11$). GNI was positively related to female parliamentary participation ($r = .51$, $p < .01$), female labor force participation ($r = .63$, $p < .001$), and female secondary education. Moreover, GNI was negatively related to maternal mortality ratio ($r = -.40$, $p < .05$), adolescent fertility rate ($r = -.52$, $p < .01$), and GII ($r = -.66$, $p < .0001$).

Table 3. Correlations between mean national 2D:4D and six measures of gender inequality

Measure of Gender Inequality	R2D:4D Male	L2D:4D Male	R2D:4D Female	L2D:4D Female
% Female Parliamentary Seats	-.39*	-.27*	-.69***	-.61***
% Female Labor Force Participation	-.40*	-.37*	-.69***	-.65***
% Female Secondary Education	-.23	.001	-.26	-.23
Maternal Mortality	.44*	.03	.11	.16
Adolescent Fertility Rate	.60**	.12	.27	.36
Gender Inequality Index	.55*	.15	.53*	.59**

Note. * $p < .05$; ** $p < .001$; *** $p < .0001$

The striking similarity between the correlations of male and female 2D:4D and measures of gender inequality undoubtedly arise because mean male and female 2D:4Ds are linked. Moreover, gender inequality is linked to GNI. Therefore, it was necessary to consider the relationship between female 2D:4D independent of male 2D:4D (i.e., *res2D:4D*) and gender inequalities independent of GNI. We performed multiple regressions with gender inequalities as dependent variables and *res2D:4D* and GNI as independent variables (see Table 4).

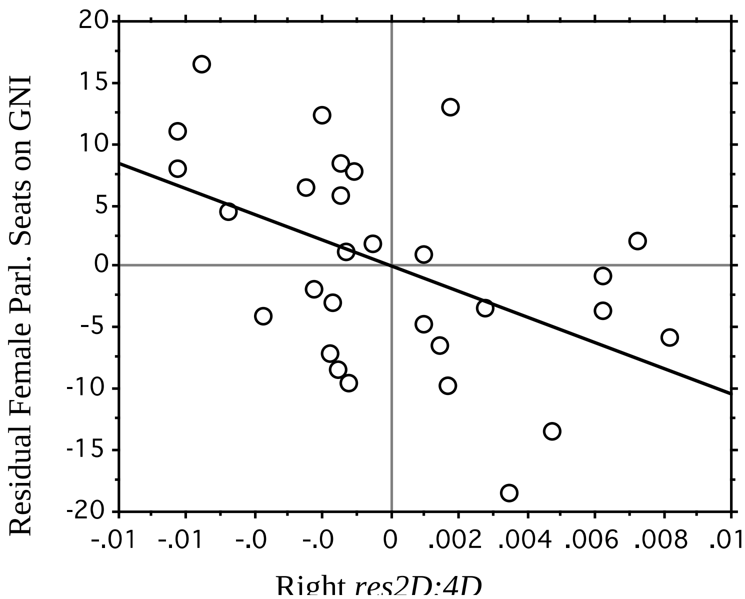
We found that independent of GNI, *res2D:4D* was significantly negatively related to female parliamentary seats and to female labor force participation. These relationships were strongest for the right hand; in the case of female parliamentary seats, *res2D:4D* was a stronger predictor than GNI. In order to visualize these relationships, we removed the influence of GNI from female parliamentary seats and female labor force participation and regressed these variables on *res2D:4D* (see Figures 1 and 2).

There were no significant associations between *res2D:4D* and female secondary education, maternal mortality ratio, or adolescent fertility rate. Summing across gender inequalities (to obtain GII) weakened the relationship with *res2D:4D* such that *res2D:4D* was only marginally related to GII and only on the left hand.

Table 4. Multiple regressions with gender inequality measures as dependent variables and *res2D:4D* of the right hand (A) and left hand (B) and GNI as independent variables

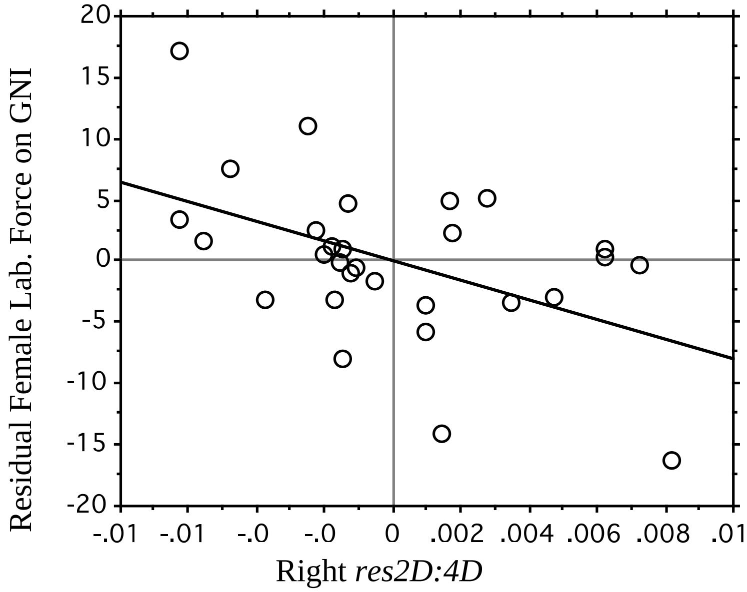
	% Parl. Seats Female	% Labor Force Female	Education Attainment Female	Maternal Mortality	Adolescent Fertility	Gender Inequality Index
(A) *res2D:4D* Right	*b* = -1152.24 *d* = -0.46 *p* = 0.006	*b* = -887.55 *d* = -0.41 *p* = 0.006	*b* = -26.72 *d* = -0.005 *p* = 0.98	*b* = -837.39 *d* = -0.24 *p* = 0.21	*b* = -524.14 *d* = -0.18 *p* = 0.32	*b* = 3.04 *d* = 0.13 *p* = 0.41
GNI	*b* = .0004 *d* = 0.36 *p* = 0.03	*b* = .0004 *d* = 0.50 *p* = 0.001	*b* = .001 *d* = 0.55 *p* = 0.003	*b* = -.001 *d* = -0.47 *p* = 0.02	*b* = -.001 *d* = -0.57 *p* = 0.003	*b* = -.000006 *d* = -0.62 *p* = 0.0004
(B) *res2D:4D* Left	*b* = -994.38 *d* = -0.40 *p* = 0.04	*b* = -713.67 *d* = -0.34 *p* = 0.05	*b* = 294.34 *d* = 0.06 *p* = 0.75	*b* = -257.38 *d* = -0.07 *p* = 0.73	*b* = 305.49 *d* = 0.10 *p* = 0.60	*b* = 7.36 *d* = 0.31 *p* = 0.06
GNI	*b* = .0003 *d* = 0.30 *p* = 0.11	*b* = .0004 *d* = 0.46 *p* = 0.01	*b* = .001 *d* = 0.59 *p* = 0.005	*b* = -.001 *d* = -0.44 *p* = 0.05	*b* = -.001 *d* = -0.46 *p* = 0.03	*b* = -.000005 *d* = -0.50 *p* = 0.005

Figure 1. The relationship between national mean right *res2D:4D* and female parliamentary seats



Note. Corrected for GNI (i.e., the residuals of female parliamentary seats are regressed on GNI).

Figure 2. The relationship between national mean right *res2D:4D* and female labor force participation



Note. Corrected for GNI (i.e., the residuals of female labor force participation are regressed on GNI).

Discussion

As predicted, male mean 2D:4D was lower than female mean 2D:4D across nations and the effect size was greatest for the right hand. This indicates that men may have experienced higher levels of prenatal testosterone and lower levels of prenatal estrogen than women. In general, male mean 2D:4D was positively correlated with female mean 2D:4D and this effect, as is often the case in 2D:4D studies, was also greatest for the right hand. However, the disparities between male and female mean 2D:4D were not constant across nations. Residuals of female mean 2D:4Ds on male mean 2D:4D (*res2D:4D*) revealed the magnitude of these disparities. Some nations, such as Iceland, France, and Denmark, showed lower (more masculinized) female 2D:4D than expected in comparison to men (negative *res2D:4D*), whereas others, such as Turkey, Croatia, and the Czech Republic, showed higher (more feminized) female 2D:4D than expected in comparison to men (positive *res2D:4D*; see Table 1).

When we considered the relationships between mean 2D:4D by sex and hand and our measures of GI, we found that right 2D:4D was a stronger predictor of GI than left 2D:4D. There was also a striking similarity in the male and female pattern of correlations with GI. This suggested that selection for genes influencing prenatal testosterone levels tends to have correlated effects on both male and female prenatal testosterone concentrations. Manning et al. (2000) have proposed that such genes have sexually antagonistic consequences. That is, selection for high prenatal testosterone drives levels up (and 2D:4D down) and selection for low prenatal testosterone drives levels down (and 2D:4D up) in both male and female fetuses. High prenatal testosterone favors subsequent fertility in males but not females, while low prenatal testosterone favors fertility in females but not males. Modifying genes reduce the sexually antagonistic effect somewhat such that mean fetal testosterone levels are higher in males than females. It is the relative effectiveness of such modifiers that determines the magnitude of the national sex differences in 2D:4D (i.e., the magnitude of *res2D:4D*).

GNI per capita and women's participation in the labor market independent of GNI were linked to 2D:4D. Wealthy nations tended to have negative *res2D:4D*; i.e., where female 2D:4D was close to that of male 2D:4D, more national wealth was generated. Recent estimates suggest that closing the gender gap in the labor market would raise the Gross Domestic Product in the U.S. by 5%, in the United Arab Emirates by 12%, and in Egypt by 34%. This effect may be particularly high in rapidly ageing societies, where women's labor force participation can help offset the impact of an otherwise shrinking workforce (ICPD, 2014).

With regard to GI, wealth was positively linked to female parliamentary representation, female labor force participation, and female secondary education. In contrast, negative associations were found between wealth and maternal mortality and adolescent fertility rates. After removing the effect of GNI, we found that low *res2D:4D* was linked to high rates of female parliamentary representation and high female labor force participation.

We interpret the link between low *res2D:4D* and high female parliamentary representation and labor force participation as follows. At an individual level, it has been shown in the BBC study that low 2D:4D is associated with high dominance scores (Manning and Fink, 2008). The correlation was stronger for women than men and for the right rather than left hand. We suggest that nations with low female 2D:4D and low female 2D:4D in comparison to male 2D:4D also have women with high mean dominance scores in relation to those of men. Dominant behavior may well be useful in gaining parliamentary selection and in entering male dominated workplaces. With regard to the latter, it has been reported that women in professions with high percentages of men tend to have low right 2D:4D (Manning et al., 2010).

In conclusion, we show that national means for female 2D:4D, independent of male 2D:4D, tend to be negatively correlated with rates of female parliamentary representation and female workforce participation. The effect was greatest for the right hand. That is, in nations in which women tend to have high prenatal testosterone and low prenatal estrogen in comparison to men, there is a tendency for greater gender equality with regard to parliamentary representation and labor force participation. We suggest that in this instance, the tendency for increases in gender equality is associated with prenatal testosterone-related dominance in women.

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